PHYSIOGRAPHIC STUDIES IN THE SAN JUAN DISTRICT OF COLORADO[1]

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The studies during the past field season were carried on near the southern and southwestern margin of the San Juan Mountains and over the adjoining plateau district. Investigations were planned for the purpose of working out the complete physiographic history of the district. The courses of the Pleistocene glaciers were indicated on the maps and the deposits left by those glaciers differentiated. In connection with these studies it was possible to differentiate the moraines of two distinct glacial epochs in each of the large canyons examined. Beyond the terminal moraines of each epoch and extending for many miles down stream, terrace remnants of valley trains were recognized. It was evident from the position of the younger glacial moraines and younger outwash valley trains that there had been a notable amount of valley deepening in hard rocks during the interglacial epoch. This suggests that the mountain area had been elevated by at least several hundred feet relative to sea-level during the Pleistocene period. The glacial features on the south slope of the range did not differ from glacial features which have been fully described by various writers who have become familiar with glacial phenomena in the high mountains of the West.

In examining the areas which rose above the upper limit of ice action on the south slopes of the mountains, certain gravel-strewn surfaces were found. The gravels were beautifully polished and of very resistant material. They were composed chiefly of quartzite, quartz, red jasper, flint, cherts, and greenstones. Much of the material was less than half an inch in diameter, but some of the pebbles ranged between one and two inches in their longer

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axes. The surfaces on which these gravels were found were along the crests between the great mountain canyons and on the tops of mesa-like hills near the base of the range. If the gravel-strewn surfaces were extended they would unite and form a plain of gently rolling topography. That plain would slope away from the core of the range, show a distinct warping at the base of the range, and pass off over the upland surfaces of neighboring plateaus. The nature and distribution of the gravels suggested that they were remnants of stream deposits in channels which formerly crossed the present inter-canyon ridges. They appeared to be the deposits of streams which flowed over low gradients and suggested further, by their distribution and the distribution and relations of the surfaces on which they were found, a deformed peneplain. In following this ancient erosion surface southward and southwestward over the plateau district it seemed that certain of the outlying mesa surfaces would correspond in age to this peneplain surface, and it was anticipated that on such outlying surfaces a mantle or scattering of still finer gravels might be found. But these mesa surfaces were found to carry a heavy mantle of bowlder-gravels, in which the larger masses ranged up to three and four feet in diameter. In these bowlder-gravel deposits certain special bowlders could be recognized which came from outcrops in the mountain areas, and it appeared that they must have been washed out and deposited as a portion of a great alluvial fan about the margin of the mountains. These bowlder-strewn surfaces were followed southward nearly fifty miles from the base of the range, and at that distance the larger bowlders seen ranged to at least three feet in diameter. The interpretation of this bowlder-gravel mantle and its relation to the erosion surfaces upon which it rests and the erosion surfaces in the mountains which seem to correspond in age to those underneath the bowlder-gravels is that at the close of the cycle of erosion during which the peneplain as described was developed, there was a general uplift in the district, which was emphasized in the San Juan dome. The headwaters of the streams in the uplifted dome were so rejuvenated that they carried together with sands and gravels many large bowlders to the base of the range and spread that material out as

alluvial fans over the neighboring plateaus. The streams which crossed the plateaus were first rejuvenated in their lower courses, and as rejuvenation worked upstream across the broad plateaus the growth of the great alluvial fans ceased and their dissection began. The high-level bowlder-gravels are, therefore, a deposit which marks the beginning of a new period of erosion in the mountains and a temporary period of alluviation about the base of the mountains. The bowlder-gravels are, therefore, not of exactly the same age, but a little younger than the small peneplain gravels of the mountain area.

Below the summit elevations in the mountains and in the neighboring plateaus there are other broad bowlder-capped mesa-like forms which appear to represent the base to which the streams worked when the peneplain was first deformed. The bowlder capping on these mesas is at places as much as thirty feet in thickness. The Florida and Fort Lewis mesas just south of the San Juan Mountains are typical of this bowlder-mesa stage in the dissection of the area. Another uplift associated with the more or less continuous growth of the mountains deformed the graded surfaces of the bowlder-mesa stage, again rejuvenated the streams, and opened another cycle of erosion. The surfaces to which the streams then worked are represented by broad, open valleys of late maturity or early old age in the softer rocks, and by canyons in the harder rocks. This cycle of erosion has been for convenience referred to as the Oxford stage, for there is an excellent development of the typical lowlands of this stage near the village of Oxford, a few miles southeast of Durango. It immediately preceded the first epoch of glaciation as recorded by the moraines and outwash deposits found on the south slope of the range. In the mountain-canyons the bowlder-mesa and Oxford stages are both represented by rock benches which in some instances carry stream alluvium.

These studies have opened certain large problems in the relationship of the mountains to the plateaus, and suggested a close correlation in the physiographic histories of the two provinces. Are the high-level bowlder-gravels resting on a true peneplain? Of what age is this peneplain? In the area examined during the

past season it is known to truncate Wasatch beds. Is it not, however, as late as late Miocene? Does it correspond in age to the great peneplains of the Grand Canyon district?[1] Are the high-level bowlder-gravels bordering the Front Range of the Rocky Mountains, the Big Horn Mountains,[2] the Livingston Range[3] of the same age as these about the San Juan Mountains? Do they rest on peneplain surfaces? Is the Blackfoot Peneplain of Montana described by Bailey Willis[4] of the same age as the one observed in this region? Are the Wyoming conglomerates about the base of the Uinta Mountains, placed in the Pliocene by the King Survey,[5] of the same origin and age as the high-level bowlder-gravels south of the San Juans? What is the relationship of certain bowlder deposits found near the summit and near the core of the San Juans, and certain ancient stream gravels which have been found by Stone, near the summit of the Front Range, to the bowlder-gravels about the bases of these ranges? Numerous other correlations in the Rocky Mountain areas and in the Pacific Coast mountains are suggested. Has there been with each period of mountain growth in the Cordilleran region of North America a rejuvenation of the streams which affected the headwaters long before it affected the middle courses of the rivers, and did these rejuvenated headwaters distribute the bowlder-gravels in each case on the neighboring plateaus? How far were such deposits carried and how were the larger bowlders transported? Numerous cases may be cited where bowlders ten to twelve feet in diameter have traveled at least twenty-five miles from their sources over surfaces of very low gradient. If such bowlders can travel twenty-five miles on gently sloping surfaces, is it not possible for them to travel much farther than that over low gradients? How are huge bowlders transported over nearly horizontal surfaces? How far have climatic changes affected the work of streams in the Rocky Mountain region? Are the reported glacial deposits in southeastern

[1] H. H. Robinson, *Am. Jour. Sci.*, 4th Series (1907), XXIV, 109–29.

[2] Salisbury and Blackwelder, *Jour. Geol.*, II (1903), 220–23.

[3] Bailey Willis, *Bull. Geol. Soc. Am.*, XIII (1902), 329–30.

[4] *Op. cit.*, 310.

[5] Hague and Emmons, *Rep. of 40th Parallel Survey* (1877), II, 64–65, 188–89 ff.

Utah,[1] in which there are granitic and gneissic bowlders one to five feet in diameter, the origin of which is at present unknown unless it be the San Juan Mountains, true glacial deposits or stream deposits? Could mountain glaciers from the San Juan Range have reached southwestward one hundred miles from the base of the range? Is there not some other explanation for the coarse bowlder deposits reported in that portion of the plateau district?[2] Has there been a continuous or periodic growth of the San Juan dome during late Tertiary and Quaternary times?[3] How are the great systems of fissures which cut the late Tertiary volcanics related in age to the recent deformative movements? Co-operative work by all who are engaged in field studies in the Rocky Mountains and plateau provinces should prove of great value in promoting the solution of these problems.

[1] D. D. Sterrett, *U.S. Geol. Survey, Mineral Resources* (1908), Pt. II, 825 (1909).

[2] W. M. Davis, *Proc. Am. Acad. Arts and Sci.*, XXXV (1900), 345–73.

[3] Cross and Spencer, *U.S. Geol. Survey 21st Ann. Rep.* (1900), Pt. II, 100.